LSC Six-Month Progress Report

Organization: German/British Collaboration for Detection of Gravitational Waves (GEO600)

Report Date: August 15, 2003

Attachment C / Lasers and Optics

Over the last six months the following progress has been made:

Due to problems with the locking of the dual recycled GEO detector no engineering run or science took place in this period. Due to this fact the long-term investigations of the GEO laser were postponed to the next MOU period.

A choice was made between the three different high power stage designs (rod-oscillator, stable-unstable slab amplifier, MOPA). For this purpose representatives of the different labs visited the LZH lab and the Stanford lab for one week to perform characterization measurement of the relevant systems. At the March LSC meeting the rod-oscillator was chosen as the base-line system. See attached MEMO T030065-00-R.

After the characterization of the 100W level system the high power laser heads were redesigned to allow for a more reliable and reproducible assembly procedure and more intrinsic mechanical stability. After fabrication in the AEI mechanical workshop the first head was used to study the effect of a quarz-rod pump-light homogenizer, and of different pump-beam diameter on the laser gain, the thermal lens and aberration in the laser rod. Once the second head was ready these investigations were extended to optimize the birefringence compensation in a system of two rod-laser heads with a quartz rotator in between. Even though these experiments were successful in terms of birefringence and aberration reduction as well as small-signal gain enhancement, some discrepancies were found between the results from the numerical modeling and experiment. Investigations have to continue to understand these discrepancies.

One of the main challenges of the AdLIGO PSL will be the power stabilization. The required stability of $1*10^{-9}$1/sqrt(Hz) has not been demonstrated so far. Even though the loop-gain in the feedback control system is high enough to reduce the in-loop fluctuations to the required level, out of loop measurement show one-order of magnitude higher noise at 10Hz. Different actions were taken to understand and reduce the excess noise:

- Characterization of the homogeneity of photodiodes
- Active beam pointing stabilization off the sensing beam
- Spatial filtering of the 10W laser beam with a pre-modecleaner before sensing on the power detectors
- Reduction of acoustic coupling and index-of-refraction fluctuations by putting the PMC and the photodetectors in a vacuum system
- Path length reduction between out and in-loop detector

Even though all these points improved the performance of the power stabilization system, the required stability level could not be achieved so far. Investigations will continue in the next MOU period.

The August 2003 LSC meeting was organized in Hannover.

Benno Willke co-ordinates the work of the laser working group of the LSC. Monthly teleconferences were organized and minutes of these calls were circulated.

MEMO on the selection of a laser system for the conceptual design phase of the AdvLIGO / (T030065-00-R)

In 2001 the LIGO Scientific Collaboration (LSC) proposed a development plan for the AdvLIGO pre stabilized Laser (PSL) system. According to that plan three groups involved in the laser development for the AdvLIGO gravitational wave detector should develop a laser system at the 100W level with a good spatial beam profile and low power and frequency noise.
The three groups chose different design choices:

- *Stanford University*: Master-Oscillator Power-Amplifier Design with end or edge pumped Slab Amplifier stages
- *Adelaide University*: injection-locked stable-unstable Oscillator Design based on a side-pumped slab laser head
- *LZH*: injection-locked end-pumped rod oscillator design

The decision for the conceptual design of the AdvLIGO laser was to be made based on a series of measurements performed on the different 100W systems (see LIGO-T020122-00-Z) in August 2002. Due to the fact that none of the three designs was ready for testing at that time, the measurement and the decision was delayed to the March 2003 LSC meeting.
Both the LZH group and the Stanford group brought their laser systems into operation just within the week the measurements were planned. Due to a number of late or wrong deliveries of components and due to unforeseen problems with aging fibres no high power system was available for the measurements in the Adelaide lab.

At the LSC meeting all three laser groups gave a talk on the design of their laser system and described a concept how their system can be scaled to the required 200W level.
The measurements of the higher order mode content, the relative power noise in the gravitational wave band and radio frequencies, as well as peak-peak power fluctuations over a 10s timescales which were taken by Shally Saraf, Maik Frede and Benno Willke were presented.

After the talks the decision committee (Jesper Munch, Carsten Fallnich, Shally Saraf, Peter King, David Shoemaker and Benno Willke) had an open discussion with the following results:

a) The laser measurements were taken on laser systems that were just brought into operation without any optimization. The results were similar for the LZH and Stanford system. Hence the committee agreed that no decision could be made based on the performance of the demonstrate systems.
b) Arguments were presented for and against the potential for scaling of the concepts. Finally agreement was reached that both scaling concept are reasonable but bare some risk in them. However no evidence was presented that one scaling concepts has a higher risk than the other.
c) The group agreed, that based on technical arguments no decision could be made.
d) Based on the argument, that project delay and costs could be minimized, the injection-locked rod oscillator concept was chosen as the best design for LZH to pursue during the conceptual design phase.

e) Because of the risks involved in scaling the 80W system to 200W the committee made a clear statement, that it is very important to continue the parallel programs at Adelaide and Stanford. Technical arguments will be revisited after the conceptual design phase in 2004. A significant technical differential at that time could lead to a change in baseline design.

The committee recommends to the GEO experimental Principal Investigators and the LIGO directorate to choose the injection-locked rod oscillator as the baseline system for the AdvLIGO pre-stabilized laser system (PSL). This concept should be studied in the conceptual design phase. Key questions to be answered at the end of the conceptual design period are, whether or not the 200 W power level could be achieved and whether or not the stabilization concept can be demonstrated close to the requirements for the PSL.